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EVALUATION OF PREDICTED SUBJECT-SPECIFIC TEMPORAMANDIBULAR JOINT KINEMATICS

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INTRODUCTION

Treatment of orthodontic disorders, such as malocclusion, is typically planned based on static information such as x-rays and imprints. However, the resulting temporomandibular joint (TMJ) mechanics, i.e. joint forces and kinematics, is typically not systematically evaluated when planning the intervention. While this would be beneficial, there is currently a lack of a validated approach to estimate TMJ kinematics and forces based on clinically obtainable data.

Therefore, the aim of this study was to develop a subject-specific musculoskeletal model of the mandible and evaluate the predicted TMJ joint kinematics against measured kinematics obtained through a gold standard.

METHODS

A subject-specific musculoskeletal model of a male subject (age 40, mass 70 kg) was developed in the AnyBody Modeling System (AMS, AnyBody Technology A/S) with the model geometry obtained from a cone beam computed tomography (CT) (NewTom 5G, QR Verona, Italy) segmented using Mimics (Materialise, Belgium). The model was equipped with 24 Hill-type muscles with the origin and insertion estimated based on the model of de Zee et al. [1].

Two different models of the TMJ were developed: 1) a point-on-plane (POP) model where the most superior point of each condyle was constrained to a plane angled 30° downwards and canted 5° medially relative to the Frankfurt horizontal plane [1]. 2) A model where the movement of the TMJ in the same three degrees of freedom (DOF), that were constrained in the POP model, were resolved by assuming quasi-static force equilibrium between all acting forces in the model at each time step in the analysis. The acting forces were gravity, inertial forces, contacts between mandible and skull, modeled using an elastic foundation contact model, and the TMJ ligament. These movements were resolved by the Force-dependent Kinematics (FDK) solver in AMS [2].

To accurately measure the movement of the mandible relative to the skull, a custom brace was developed based on a dental impression onto which retro-reflective markers were affixed (Figure 1). The trajectories of these markers were tracked by eight infrared high-speed cameras and collected at 100 Hz (Qualysis, Sweden).

While wearing the brace, the subject was instructed to, among others, open and close his mouth consecutively for 10 seconds after which the process was repeated. Subsequently, the first five completed cycles were extracted and used as input to the model to drive the three DOF not controlled by the TMJ models and to validate the three DOF estimated by the model.

RESULTS AND DISCUSSION

The measured and predicted kinematics of the open-close task are depicted in Figure 1.

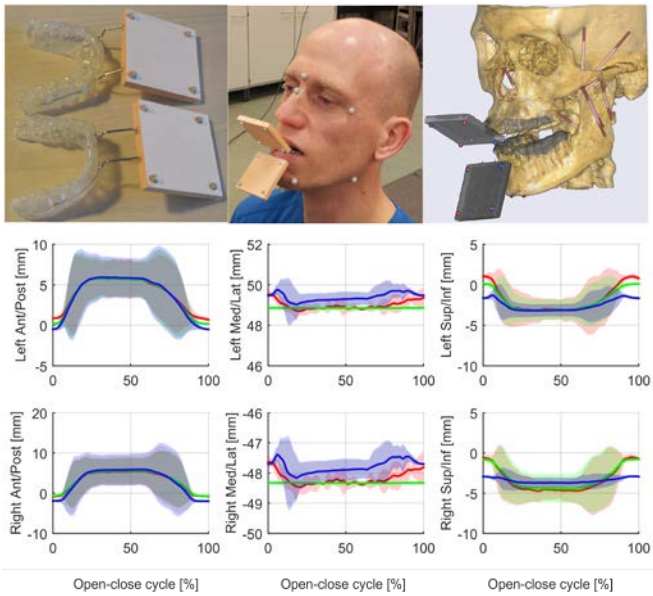

Figure 1: Top row from left to right: the subject-specific brace, the subject wearing the brace during the motion capture session and the musculoskeletal model driven by the measured marker trajectories of the brace. Middle and bottom rows: Predicted left (middle) and right (bottom) joint kinematics during an open-close cycle of the FDK TMJ model (blue), POP TMJ (green) and measured kinematics (red). Shaded areas indicate ±1 standard deviation.

The POP model predicted the movement of TMJ with a Root-Mean-Square (RMS) error of at most 0.47 mm (Sup/Inf direction) and with a Pearson's correlation coefficient above 0.98 for the Ant/Post and Sup/Inf directions. The Med/Lat direction showed poor correlation (0.14). The FDK model showed comparable results although the RMS errors were higher (at most 1.41 mm) and the correlation coefficients slightly lower (0.85 or higher) for the Ant/Post and Sup/Inf directions but higher than the POP model in the med/lat direction (0.30). The improvements in the Med/Lat direction is likely caused by allowing the FDK solver to predict this movement whereas the slightly poorer predictions in the two other directions is likely caused by the simplified representation of the TMJ geometry, where especially the contribution of the TMJ disc was omitted.

CONCLUSIONS

In this study, we presented a subject-specific musculoskeletal mandible model and evaluated the predicted joint kinematics for two different models of the TMJ against measured joint kinematics. The model represents an important step towards enabling evaluation of subject-specific TMJ mechanics that may ultimately be used when planning orthodontic treatments.

REFERENCES

1. de Zee M, et al, *J. Biomech.* **40**: 1192-1201, 2007.
2. Andersen MS, et al, Proceedings of TCGS, Leuven, Belgium, 2011

→Left side margin 1.5cm ↓Margin from the top 2 cm↓ Right side margin1.5.cm ←

↑Margin from the bottom 2 cm↑